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Mobile Enhanced Learning in a South African Context

Mmaki Jantjies[1*] and Mike Joy[2]

[1]Department of Information Systems, North West University, Mafeking, South Africa // [2]Department of Computer Science, University of Warwick, Coventry, UK // mmaki.jantjies@nwu.ac.za // m.s.joy@warwick.ac.uk

[*]Corresponding author

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ABSTRACT

Multilingual classrooms in developing countries are often challenged by a lack of digital resources and technology which supports their multilingual learning process. *Code-switching* is a phenomenon common to multilingual schools where learners are taught in a language which is not their first language. In these environments, code-switchers frequently alternate between their first and second languages, seeking alternative words to clarify their understanding of the topic being studied. This paper presents a study based in South Africa, where mathematics learners interacted with a mobile learning system named M-Thuto, supporting learners who code-switch while learning and providing them with digital resources. The system consisted of summarised notes, class exercises and a class quiz. Through semi-structured interviews and questionnaires, data were gathered and analysed from 90 learners to gain perspectives on their interaction processes. The study aimed to establish how mobile learning can be used to support multilingual learners in under-resourced schools. The results of the study reflect the need for mobile learning resources that support their learning considering their linguistic challenges. The results also reflect the important role that mobile phones can play as alternative digital learning resources.

Keywords

Multilingual, Code-switching, Mobile learning, Setswana, South Africa

Introduction

In many developing countries education is often provided in a learner's second or third language, and thus learners sometimes struggle to appropriately interpret tasks and content, as a result of inadequate language acquisition in the language of learning and teaching (LOLT) (Arthur, 1996; Setati and Planas, 2012). While there has been extensive research into mobile learning for second language acquisition (Collins, 2005; Ballance, 2012; Wong et al., 2012) there is limited research that focuses on ubiquitous learning that can be used to support learning in multilingual environments.

Language forms an important part of the learning process as the learning language not only affects the learner's communication within their school but it also affects their interpretation and understanding of the learning content, especially in subjects such as mathematics which require proficient knowledge of the LOLT (Abedi & Lord, 2001).

South Africa is a multilingual country with 11 official languages. Even though there is officially one LOLT, the South African government supports the use of other languages to assist the learning process in schools (DOE, 1997) as the majority of the country's population are not English first language speakers. The South African education system is challenged by multilingual classrooms with limited learning material to support learning in these types of environments (Maree et al., 2006). With eleven official languages, teachers often face the challenge of teaching learners from multilingual backgrounds through a language that they only accurately acquire when they begin formal education. This often leads to continuous code-switching within classrooms. Code-switching is a phenomenon common in multilingual environments where a speaker always reverts to the use of two languages in a conversation. The reasons for alternating the languages could be as a result of an inadequate language vocabulary in their second language and thus the speaker will always go back to their mother tongue to seek the relevant duplicate word (du Plessis & Louw, 2008). This problem is not unique to South Africa and is mostly observed in learning environments where the LOLT differs from the learner's home languages (Lin, 1996; Arthur, 1996; Moschkovich, 2007). Developing mobile learning applications that can be used in subjects such as physical sciences, mathematics, history, etc., to support such environments requires appropriate content which considers the user's challenges and needs.

The objective of the research project reported here was to establish potential solutions to the following research questions.

- What are the challenges associated with learning content that code-switching learners face in formal learning environments?
- What are the resource needs of learners in under-resourced learning environments?
- How can mobile learning be used to support learners who code-switch in under-resourced environments?

This paper evaluates, through a case study, a proposed mathematics bilingual mobile learning application named M-Thuto which was developed to support learners in South Africa. M-Thuto is a web-based tool which is accessible on a WAP enabled mobile phone, and aims to be a comprehensive learning tool consisting of the learner's class-notes, interactive class exercises with suggested worked solutions, and a class quiz to test the learner's understanding of the learning content. M-Thuto uses the code-switching technique of learners to present mathematics content in both the Setswana and English languages. The study was conducted in a predominantly Setswana speaking area, while English is the LOLT in the schools under study. The name M-Thuto is derived from both the English and Setswana language which is mobile education (thuto). The development of this application was also motivated by the shortage of reading and learning material in some South African high schools.

The study presented in the paper was facilitated over a period of a month with learners from four different schools interacting with the application and subsequently giving individual feedback at the end of the study. Subsequent to the interactions, surveys were conducted with learners giving feedback on the learning process and the language support of M-Thuto on their mathematics subject. Teachers also participated in the study with the M-Thuto system giving them provision to monitor the learners' interactions with the tool through the teacher's personal access portal. The results of the study provide support for methods to be considered when creating a multilingual mobile learning environment towards a proposed multilingual mobile learning framework.

Literature background

Mobile learning

Mobile learning has been defined by different researchers, with each of their definitions being influenced by their perspectives on the role it plays in the learning environment. Some mobile learning definitions follow a more technical approach which concentrates on the mobile learning platform, while other definitions focus on the pedagogy experience and the ubiquitous nature of the mobile learning process (Traxler, 2007). The working definition used in this paper will proceed from the description provided by Kukulska-Hulme et al. (2009, p. 20) that the process of mobile learning is affected by ubiquitous learning practices that, "cross spatial, temporal and/or conceptual borders and involve interactions with fixed technologies as well as mobile devices. Weaving the interactions with mobile technology into the fabric of pedagogical interaction that develops around them becomes the focus of attention." In this paper we consider the learning language as an important part of the pedagogical interaction process. Mobile learning provides a learning platform across learning spaces through the contextual language as a learning resource in which pedagogy is delivered through the ubiquitous learning process.

Multilingual learning content

The Internet is one of the first and most widespread methods of education delivery through electronic media, with people accessing it on their mobile and desktop devices. Until recently, English was generally the primary language used to deliver online content. The use of Arabic and Chinese languages on the Internet has grown rapidly in recent years, and this has led to an increase in the number of indigenous language speakers using the web. The translation of web pages into other languages has also reflected a proportional growth in Asian, Arabic and European languages (Chung, 2008), and there has been a consequent increase in the number of multilingual websites. Previously there was an absence of African languages used in electronic media, with no options provided in the language choice features of any form of electronic tool (Osborn, 2006). Even though there has been progress in the use of African languages in electronic media, African language options still remain limited.

In mobile learning empirical studies, there is evidence of the effectiveness of mobile learning applications which aim to support content accessibility in multiple languages across different subject areas. For example, Yoza is a mobile novel book application that was initiated to mitigate the lack of access to books by South African youth. The

application provides mobile device accessible novels which are available in both English and Xhosa (one of the 11 official South African languages). The content of the application is viewed on a mobile phone through a Mixt platform which provides online access to different resources at affordable prices. The Yoza initiative has grown to include access to broader literature which includes short stories, novels and poetry (UNESCO, 2012). After each session the readers can give feedback on the story they have read. UFractions is another example of an m-learning tool replicated in multiple languages which is available in English, Finnish and Portuguese, and has been piloted in South Africa, Finland and Mozambique. UFractions is a mathematics mobile game that enables high school learners to learn fractions by solving some tasks on their mobile phones (Turtiainen et al., 2009; Laine, 2011). Each of these applications was developed for a specific context. Despite the context and language support provided by each of these m-learning applications, code-switching features and language adaptation elements were not utilized to fully support the bilingual learner.

The proposed multilingual mobile learning content design

Multilingual learning environments and the practice of code-switching

Code-switching is defined as the use of more than one language in an utterance or during a conversation. The behaviours of code-switchers often differ between the informal and formal contexts. In formal learning environments, especially in formal writing, code-switching occurs less frequently compared to informal environments (Graedler, 1999). While other researchers view code-switching as a barrier to mastering the LOLT in classrooms (Pfaff, 1979), most researchers view code-switching as a unique strength that second language speakers of LOLT have to view and understand learning in more than one language (Arthur, 1996). In learning environments, code-switching is used as a scaffolding mechanism that can help learners who are not first language speakers of the instructional language to understand learning content in a second language (Adler, 1998; Fennema-Bloom, 2009). In a typical classroom where code-switching occurs, the teacher will move between the language of instruction and the learner's home languages to either reinforce the learner's understanding or to introduce new challenging topics (Setati, 1998; Fennema-Bloom, 2009).

The effect of code-switching is often more visible in classrooms where the teacher is also not a first language speaker of the LOLT (Ncoko et al., 2000; Setati & Adler, 2000; Probyn, 2006; Moschkovich, 2007; Carless, 2004; Mbali & Douglas, 2012). In such environments both the teachers and learners always revert back to code-switching and attempt to recreate the content in the learner's first language, to give a clear understanding of the learning content. Setati (1998) observed a classroom in South Africa to establish how code-switching occurred. In her studies she revealed that teachers in formal classrooms use code-switching in the following ways.

- To reinforce a concept – this occurred when a learner would ask a question in class related to what the teacher had just taught using the official LOLT. The teacher would revert between the learner's home language and the LOLT to give clarity to the learner's question.
- To explain new concepts – this occurred when a teacher was introducing a new concept in class. The teacher would explain the topic in the LOLT and would then explain the topic in the learner's home language.
- Translation – this occurred when a teacher would directly translate text from the LOLT to the learner's home language.

In this paper we consider Setati's (1998) code-switching methods and use them to create learning content that can be used to support mathematics learners through the M-Thuto mobile learning environment.

Case study

Learners from different schools based in both urban and rural locations participated in this case study. The difference in locations outlined the difference in learners' needs and challenges related to language and access to electronic learning resources. In the study, learners were provided with mobile phones during their mathematics classes and required to interact with the system and provide feedback on their interaction process. After using the system, learners provided feedback though interviews and questionnaires. The languages used for the M-Thuto system were English and Setswana, as Setswana was the common native language of the geographical location were the study was conducted and the English language was the language of teaching and learning in the participating schools.

The M-Thuto software

The architecture of the application in this study is based on a client server layout. The learning content is accessible through any WAP enabled mobile phone. The learner's mobile phones access the application and related content on the server, and an SQL database is also stored on the server. The database includes the learner's interaction details and results from their quiz. The choice of this architecture was influenced by the available network and resources, and it was important to develop content that would be accessible even on the most basic web-enabled mobile phones. Each learner has their own profile keeping records of their individual interactions and performance. Basic open source web development languages XHTML and PHP were used to design the application interface and enable communication with the database during learner interaction. The learning content was developed in consultation with a mathematics specialist who was previously a teacher and now a head of department in the local government where the research occurred. Teachers and language translation specialists also participated in the content development process.

The purpose of the application was to provide a comprehensive tool that also reduces the problem of resource shortage faced by some of the participating schools. The learning content was structured in a menu using the as follows.

Class Notes – The first section of the system was a notes section, these notes were simplified teachers' notes of the topic of simultaneous equations that they had covered in class.

Class Exercises – The second section was a class exercise questions page that allowed learners to practice potential examination questions. Each question had a hidden answer that a learner could only reveal after attempting the question. The learners would then view the correct answer to the questions reflecting on other methods they could have used to answer it.

Class Quiz – The third section was a class quiz which allowed learners an opportunity to test their understanding of the topic area. Their answers were sent to the database for teachers to keep track of.

Attributes – The final section was as an acknowledgement section that acknowledged the parties that contributed to the development of the learning content including the translation of the content.

The M-Thuto activity menu choice

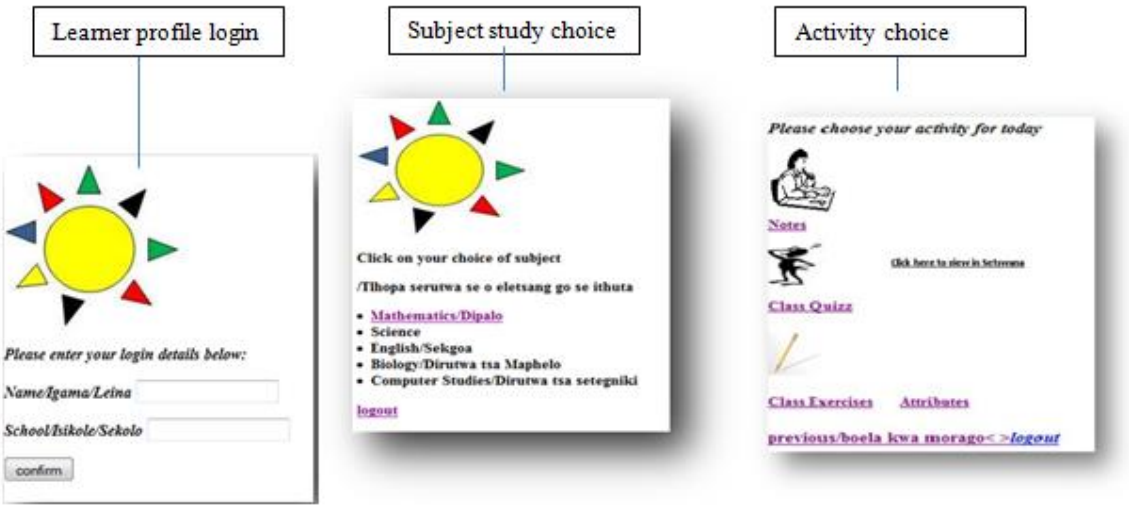


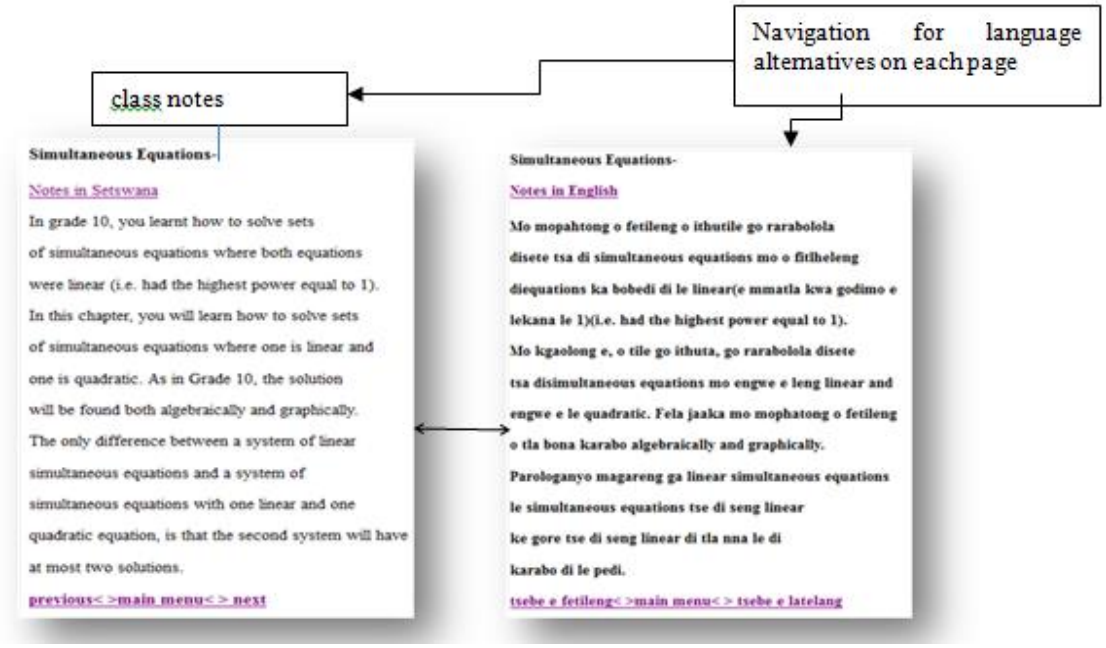
Figure 1. The learner interaction pages with M-Thuto (Jantjies and Joy, 2014)

Code-switching attributes

The content support for code-switching of this system was based on Setati's (1998) code-switching type principles. Setati mentions three ways in which code-switching is used in the classroom learning environment. These three approaches are adapted to the mobile learning environment to present three methods that can be used to create a mobile learning system to support the code-switching behaviour.

Introducing content activity: When new concepts are introduced to learners, learning content is provided to learners in micro-paragraphs, using the LOLT and then the same content is recreated in a different language using the learner's home language and presented to the learner. Appropriate navigation features are required as the learners will need to move between the learning pages to achieve this code-switching support.

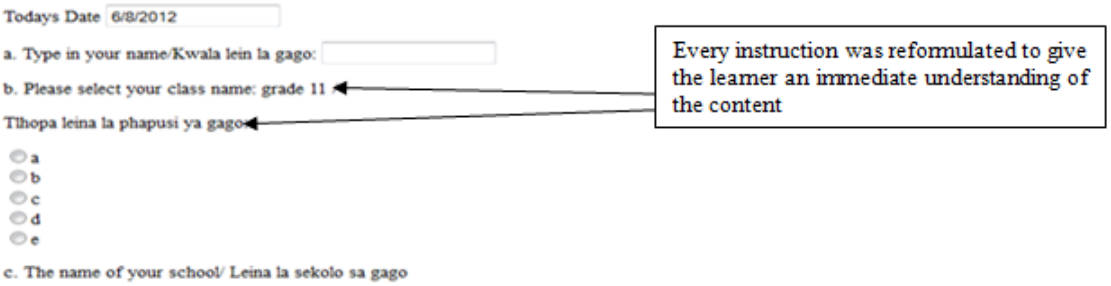
An example of introducing content activity in the M-Thuto system:



(Jantjies and Joy, 2014)

Reformulation: In this form of code-switching learners are provided with a rephrased wording of the same content in a different language. This support is provided with lines of content in different languages preceding each other.

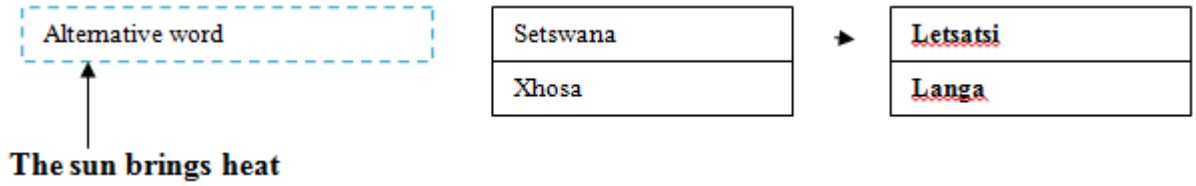
An example of reformulation in the M-Thuto mobile quiz:



(Jantjies and Joy, 2014)

Translation: this is the direct translation of words, but is often not used in classrooms to facilitate the code-switching environment. This is as a result of direct translation often distorting the meaning of the content. In this paper we suggest an alternative means of translation by giving learners an option to view an alternative word in another language. A similar feature has been used by the North West University (Van Huyssteen et al., 2007) to support multilingual learners. This paper proposes a selection option of the word within text which enables the learner to view an alternative word in another language (the learners home language) giving a direct translation of the word. On the mobile application a learner would be given a text and select a word which they are not clear to view its alternative in another language instead of viewing the full paragraph in another language as presented above in the *Introducing content activity* example.

An example of translation:



(Jantjies and Joy, 2014)

The research methodology

A sample of 90 learners from four public schools within the North West province participated in this research. The schools were situated in different geographic setting with one school situated in a township, two schools located in rural villages and the last school in an urban area. The learners' ages ranged between 16 and 18 years with these learners distributed across grades 11 and 12, which are the last two years of secondary school in the South Africa education system. All learners in the research process were registered for mathematics as one of their school subjects. In order to conform to ethical requirements, a formal request to perform research was submitted to the North West department of education.

Mobile phones are prohibited for use in schools and a request was made to each school to allow their use for the research, and the learners each received a WAP enabled mobile phone for the research process. Despite this, some learners came with their own mobile phones and interacted with the tool through their own phones. The tool was accessible online with each mobile phone having airtime to access the Internet. Some lessons during the week were dedicated to this mobile learning process. Each individual learner chose an activity that they wanted to focus on for the day.

Content developed for the research process was based on the topic area of simultaneous equations with topics ranging from grade 10 to grade 12 content. Each page of content had an interchangeable option with a choice to view it either in Setswana or English, allowing the learner to change their view at any time during their study. The content was divided into three learning areas: notes designed by teachers for daily learning, a section consisting of class exercise questions and answers in the form of a drilling method, and finally a section to test learners' understanding of the topic through different tests. The learners spent most of their time on the class exercises as they enjoyed receiving real time guided alternative answers to the questions they had attempted during the interactive drill and answer process.

Learners subsequently filled in questionnaires on their interaction process with the researchers present, allowing the learners an opportunity to ask for any further clarity on the questionnaires. The questionnaires allowed the respondents to be free in expressing their views without the feeling that they were being monitored, and mostly consisted of closed questions. Learners were also interviewed through semi-structured interviews, which are guided but are flexible in allowing the interviewer to gain more content beyond the guided question format (Cohen et al., 2011). The research took place over a month.

Data were divided and discussed through the thematic analysis process which concentrates on the response of the participant as opposed to the manner in which they responded (Bryman, 2004). The data gathered from the interviews and questionnaires are discussed below, with fictitious character names to hide the participants' identities.

Study results

Code-switching challenges

This section was based on Moschkovich (2010) who explains that in order to understand a multilingual learning environment the researcher needs to know the linguistic background of the learners and how their bilingual nature affects their learning process. This section sought to establish the linguistic backgrounds of learners and how being bilingual affected their learning process in their mathematics class.

The types of questions in the surveys included the following.

- How many of the South African languages can you speak, read and write?
- Do you ever have challenges in understanding content when provided with content or instructions through the language of learning and teaching which is English?

Results

100% of the learners were able to communicate effectively in two or more languages which included their home language and English which was the LOLT. From the eleven official languages, 89% of the participants could effectively communicate in Setswana and English. The high number of first language Setswana speakers was influenced by the geographic location of the study. Knowing the languages specific to a geographic location enables content developers to create content which considers the specific locations giving users language options familiar to them. When asked about their challenges in understanding the language content presented for monolingual speakers, a collective of 53% of participants agreed that they often incurred problems understanding content as a result of the language that it is presented in. As seen in figure 2, when looking further at the data, the schools reflected the difference in the local area use of languages. Schools located in the rural areas and townships where English was not commonly used for communication, had the highest number of children consenting to this challenge with 67% of learners in schools C and D, followed by 60% in school B. School A, located in an urban area where English was commonly used for communication along with Setswana, presented only 42% of learners as having this problem while learning. Learners from urban schools such as school A, had also often received good English foundation in their primary school years. From these learners, a collective of 63% of the learners stated that thus often code-switched while learning during class.

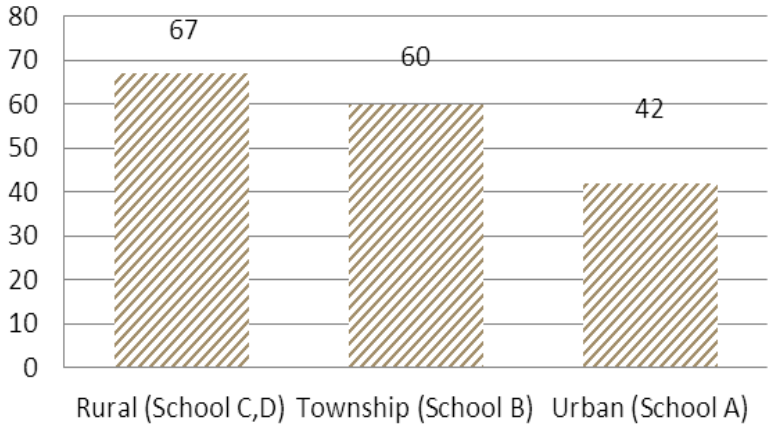


Figure 2. The percentage of learners who struggle to understand content

The role of mobile learning in an under-resourced environment

As schools in low income areas would also struggle with having sufficient learning resources to support each learner, the questions in this section sought to establish the electronic learning resources that participating learners already had access to which could give them access to additional learning material. The questions also sought to establish if the existing digital resources made provision for their bilingual learning. Considering the low cost of mobile phones and high access that learners have to mobile phones this section aimed to establish the role that mobile learning could support the learning process in under-resourced bilingual environments.
The types of questions in the surveys included the following.

- Do you own a mobile phone?
- If your answer for the previous question was *no*, do you have access to a computer at home?
- Are you ever needed to use electronic devices as part of your learning (i.e., search the Internet to gather data?

Results

From the four participating schools only one school had computers available for learning within the school. All participating learners either owned or had access to a mobile phone at home, while there was poor ownership and access to computers. The responses however differed with each school location with school A in a high income area displaying a different array of results from learners in schools B, C, and D which were based in low income areas.

When questioned about their history with electronic learning, learners from school A mentioned that they used the Internet to access learning resources and knew where to access further learning resources through their mobile phones. The teacher in school A was also very knowledgeable about external resources that learners could use to supplement their learning process and motivated them to use those resources but in their informal home environments.

The learners in the low income areas (schools, B, C, and D) were completely reliant on paper based learning material received from their schools and could not afford learning material beyond this. Many of these learners were unaware of web-based or electronic and mobile learning resources and games.

From the participants in all schools, 56% of learners mentioned that they were sometimes given tasks that required the use of technology through either online research or typing their work. However, as seen on figure 3, only 22% of participating learners could access a computer to perform these tasks, whereas 48% of the participating learners owned a mobile handset and other learners had access to them. Access to mobile phones in comparison with other electronic learning devices reflected the potential that mobile learning had in supporting the learning process of the participants. All learners had access to a mobile phone at home. Mobile learning also had a potential for providing more learners with access to resources as most of the participating learners did not have access to other digital learning resources and were at times required to use computers for doing their homework.

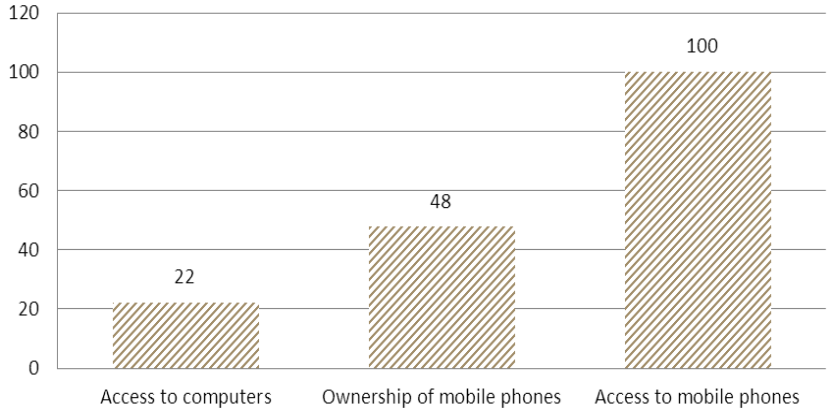


Figure 3. The percentage of all participants' access to technology

In schools C and D learners would at times not have enough learning material such as prescribed text books for each learner to use at their own convenience. This meant that learners would occasionally have to share learning material which they would have access to in order to obtain learning material. Having access to mobile phones, provided them with access to mobile Internet which served as an additional resource to accessing learning material such as online mobile books.

Using mobile learning to support learners who code-switched in under-resourced environments

The questions in this section sought to establish the learner's previous experiences of electronic learning and their experiences in using the M-Thuto system. The objective of this section was to establish the applied use of content view principles in supporting the code-switching learners through a mobile learning system and how this system could support schools challenged by a lack of electronic learning resources.

The types of questions in the questionnaire included the following.

- Have you ever used a mobile application for learning?
- If your answer for the previous question was *yes*, was the application a learning system or an educational game?
- In the M-Thuto system which of these languages did you use to read the learning content?
- Do you find the system effective in supporting the learning process?
- What are the challenges you faced with the mobile learning process?

Results

From the participating learners, 53% of them had previous experiences of interacting with mobile education applications, but all of these interactions were only game based and were not directly related to their current studies. All of the learners with previous experience came from the urban school A, which is consistent with the results above that learners from schools B, C, and D had limited access and knowledge of electronic learning resources. M-thuto was used to support learning during lessons and thus compensating for the resources such as text books which were needed by each learner as the system was able to provide notes and exercises which could also be accessible through their books. During this study every learner thus had access to the resources at their own convenience as the system also gave them access to the Internet to enable them to use online mathematics resources.

From the interaction process with M-Thuto, as presented in figure 4, 61% of all learners had used both English and Setswana to read the content of the application. 34% of the learners used only the English language to read content while 98% of all participants mentioned the effectiveness of the bilingual learning tool in supporting their learning process. Looking at this data further the schools in the rural and under-developed areas had the highest number of viewings in using both Setswana and English to read the content. At the end of the study the learners and teachers felt that the project should go beyond a pilot study as the learners found the mobile learning interaction process helpful towards achieving their learning objectives.

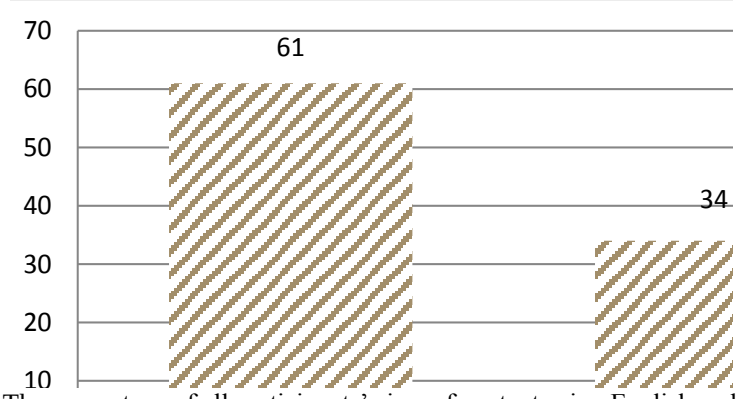


Figure 4. The percentage of all participants' view of content using English and Setswana

School A in the urban area had the highest response percentage of learners using only English to read the content. School C, which is located in a rural village, had the highest number of learners viewing content in both languages. Not a single learner used only Setswana to view the content.

Despite the code-switching nature of learners throughout the schools, the ability to read their home language was not common to all learners. The learners in the rural schools seemed to appreciate the language aspect more than those who came from the urban school. From school D, Basadi expressed the experience as "fun because we were learning on mobile phones and this made me look forward to learning. Reading content in both Setswana and English also made the process exciting because I explored my Setswana." Even though the majority of learners in schools A and B used only English to view content, most of the original language views of learners in these schools had become less stringent after their mobile learning experience. The learners were now more focused on the look and feel of the learning tool and the need to expand the tool into other subjects, giving suggestions on how to make the application interaction more fun. From school A, Itumeleng felt, "it is nice to be able to move back and forth between the languages when reading the content. If one of the languages gets too difficult I can switch back to check what the term means in another language. I however feel that the application needs more 'flash' and sound." Most of the learners in school A attended the ICT lessons which are offered in the school. Also from school A, Lesego said that "I loved the tool but I just feel that there is too much focus on mathematics, other subjects that we find difficult are neglected. Is it possible to use this tool for my other subjects?" In the rural schools where learners were very opinionated about using their home languages for learning, they took time out to read the content and learn using both languages.

Discussion

In the study above, we observed that some of the participating schools were still challenged by limited learning resources available to the learners. Even though school A (which is located in a high income urban area) was well resourced, the participating learners felt that ubiquitous learning resources provided further learning material which was effective in supporting their learning process. Learners from the remaining schools saw ubiquitous resources as a tool that would reduce their existing resource gap in support of their learning. Accessing further learning resources which they would not have to pay additional money to obtain, could enhance their learning as most of them cannot afford additional learning material (Legotlo et al., 2002).

As some schools had a challenge of providing learners with required reading material to support learning, we found that M-Thuto was able to support the need for this resource role by providing them with class notes and exercises which could also be found in their prescribed text books. Many parents in rural and low-income communities are often without a job or are employed in low wage roles such as housekeeping and gardening. These parents cannot provide beyond their means as their income is often only enough for the family basic living costs. Further costs related to their children's education or school activities become difficult to support. Propelling this situation in low income areas are the poor resources, limited books and teacher shortage experienced by learners especially in vital learning areas that require efficient resources in order for a learner to perform well (DOBE, 2011). These schools are often out of reach of public amenities (i.e., libraries and community computers) that can provide free learning resources. Considering the wide access to mobile phones in all South African communities, mobile learning emerges as a potential solution that could be applied to reduce the resource shortages in these communities (Vosloo & Botha, 2009). Learners from low-income communities located far from cities also have limited knowledge of free online and offline resources that can support their learning process. Through access to basic technology such as mobile phones, learners can enhance their learning process by accessing these resources to support their learning.

The South African education system is also facing challenges of language use in schools with learners coming from different linguistic backgrounds. Learners who participated in this research found that code-switching in their learning process and amongst their peers helpful in supporting them to clearly articulate themselves and understand tasks. M-Thuto gave them an opportunity to alternate through different ways to their home language during their learning process. The problem of not understanding tasks or being unable to articulate responses without code-switching while learning seemed to be prevalent in mathematics lessons. Mathematics requires a clear understanding of the language that it is imparted in, as this could affect the learner's interpretation of the task and their response to the task. The challenge of poor English language backgrounds and the unavailability of bilingual learning material contribute to the poor performances of learners in key learning areas such as mathematics (Botes & Mji, 2010; Setati, 2008).

The learners who had a previous experience of interacting with some form of mobile learning tool expressed that there was a significant absence of mobile learning content written in South African languages. There is a clear need to further explore the availability of mobile pedagogy delivered through various languages. Having access to appropriate mobile learning content available in a choice of languages can support learners in South Africa to enhance their learning process.

Conclusion

This paper presented a study where learners from four uniquely resourced schools interacted with mobile learning system named M-Thuto and presented their views on their interaction process. The research results from the case study, on the M-Thuto experience of the high school learners from both rural and urban school results, show that there are still learners who are in need of supplementary ubiquitous learning resources and materials. M-Thuto was able to provide them with learning notes, drill exercises and related quizzes to support their learning. Even though learners in urban participating schools could acquire and access supplementary learning material, having accessible and ubiquitous multilingual learning material assisted them to learn in their own time, in their choice of language, while introducing them to new methods of ubiquitous learning. Furthermore, by providing bilingual content support, M-Thuto gave learners the opportunity to have options in methods of viewing mobile learning content supporting their code-switching nature. Techniques such as content adaptation and efficient responsive memory provided effective design principles for developing the architecture to suit this context.

In a country where the majority of the learners are bilingual, learners must be afforded the opportunity to be able to choose which language would aid them to understand their learning content. The future of the M-Thuto system is to further enhance its architecture to support code-switchers, allowing them to access a context aware learning resource. Through various enhancements of the system a framework will be formulated which can be used to support the development of mobile learning software to be used in similar multilingual learning environments.

Mobile learning supporting bilingual or multilingual content needs to be further investigated to find effective ways to improve South African education and other under-resourced multilingual learning communities through appropriate and affordable technology.

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References

Abedi, J., & Lord, C. (2001). The language factor in mathematics tests. *Applied Measurement in Education, 14*(3), 219-234.

Adler, J. (1998). A language of teaching dilemmas: Unlocking the complex multilingual secondary mathematics classroom. *For the Learning of Mathematics, 18*(1), 24-33.

Arthur, J. (1996). Code switching and collusion: Classroom interaction in Botswana primary schools. *Linguistics and Education, 8*(1), 17-33.

Ballance, O. J. (2012). Mobile language learning: More than just “The Platform.” *Language Learning & Technology, 16*(3), 21-23.

Botes, H., & Mji, A. (2010). Language diversity in the mathematics classroom: Does a learner companion make a difference? *South African Journal of Education, 30*, 123-138.

Bryman, A. (2004). *Social Research Methods*. Oxford, UK: Oxford University Press.

Carless, D. (2004). Issues in teachers' reinterpretation of a task-based innovation in primary schools. *Tesol Quarterly*, *38*(4), 639-662.

Chung, W. (2008). Web searching in a multilingual world. *Communications of the ACM, 51*(5), 32-40.

Cohen, L., Manion, L., & Morrison, K. (2011). *Research methods in education* (7th Ed). Falmer, UK: Routledge.

Collins, T. (2005). English class on the air: mobile language learning with cell phones. In P. Goodyear et al. (Eds.) *Fifth IEEE International Conference on Advanced Learning Technologies (ICALT 2005)* (pp. 402-403), Kaohsiung, Taiwan: IEEE.

DOBE. Department of Basic Education (DOBE). (2011). Quality education for rural schools in South Africa – Challenges and solutions. *South African Rural Educator, 1,* 8-15.

DOBE. Department of Basic Education (DOE). (1997). *Language-in-education policy*, 1 – 9. Retrieved August, 12, 2012 from http://www.education.gov.za/DocumentsLibrary/Reports/tabid/358/Default.aspx

du Plessis, S., & Louw, B. (2008). Challenges to preschool teachers in learner's acquisition of English as language of learning and teaching. *South African Journal of Education 28*, 53–75.

Fennema-Bloom, J. (2009). Code-scaffolding: A pedagogic code-switching technique for bilingual content instruction. *Journal of Education, 190*(3), 27-35.

Graedler, A. L. (1999). Where English and Norwegian meet: Codes witching in written texts. *Language and computers*, *26*, 327-344.

Jantjies, M., & Joy, M. (2012). Multilingual mobile learning – A case study of four South African high schools. In M. Specht et al. (Eds.), *11th World Conference on Mobile and Contextual Learning* (mLearn 2012) (pp. 208-211). Helsinki, Finland: CEUR.

Jantjies, M., & Joy, M. (2014). A framework to support mobile learning in multilingual environments. In I. Sánchez, & P. Isaías (Eds.), *10th International conference on Mobile learning* (pp. 222-229). Madrid, Spain: IADIS.

Kukulska-Hulme, A., Sharples, M., Milrad, M., Arnedillo-Sánchez, I., & Vavoula, G. (2009). Innovation in mobile learning: A European perspective. *International Journal of Mobile and Blended Learning, 1*(1), 13–35

Laine, T. (2011). *Technology integration in context-Aware learning spaces* (Unpublished doctoral dissertation). University of Eastern Finland, Finland.

Legotlo, M., Maaga, M., Sebego, M., van der Westhuizen, P., Mosoge, M., Nieuwoudt, H., & Steyn, H. (2002). Perceptions of stakeholders on causes of poor performance in grade 12 in a province in South Africa. *South African Journal of Education, 22*(2), 113-118.

Lin, A. M. (1996). Bilingualism or linguistic segregation? Symbolic domination, resistance and code switching in Hong Kong schools. *Linguistics and Education*, *8*(1), 49-84.

Maree, K., Aldous, C., Hattingh, A., Swanepoel, A., & Van der Linde, M. (2006). Predictors of learner performance in mathematics and science according to a large-scale study in Mpumalanga. *South African Journal of Education, 26*(2), 229–252.

Mbali, C., & Douglas, J. (2012). Implementing a speaking test at Grade 6 (primary school) in South Africa. *Southern African Linguistics and Applied Language Studies, 30*(4), 525-537.

Moschkovich, J. (2007). Using two languages when learning mathematics. *Educational Studies in Mathematics*, *64*(2), 121-144.

Moschkovich, J. N. (Ed.). (2010). *Language and mathematics education: Multiple perspectives and directions for research*. Charlotte, NC: Information Age publishing.

Ncoko, S., Osman, R., & Cockcroft, K. (2000). Codeswitching among multilingual learners in primary schools in South Africa: An exploratory study. *International Journal of Bilingual Education and Bilingualism*, *3*(4), 225-241.

Osborn, D. (2006). African languages and information and communication technologies: Literacy, access, and the future. In J. Mugane et al. (Eds.), *Selected Proceedings of the 35th Annual Conference on African Linguistics,* 86-93. Somerville, MA: Cascadilla Proceedings Project.

Pfaff, C. W. (1979). Constraints on language mixing: Intrasentential code-switching and borrowing in Spanish/English. *Language*, 291-318.

Probyn, M. (2006). Language and learning science in South Africa. *Language and education*, *20*(5), 391-414.

Setati, M. (1998). Code-switching in a senior primary class of second-language mathematics learners. *For the Learning of Mathematics*, *18*(1), 34-40.

Setati, M., & Adler, J. (2000). Between languages and discourses: Language practices in primary multilingual mathematics classrooms in South Africa. *Educational Studies in Mathematics*, *43*(3), 243-269.

Setati, M. (2008). Access to mathematics versus access to the language of power: The struggle in multilingual mathematics classrooms. *South African Journal of Education* 30, 123-138.

Setati, M., & Planas, N. (2012). Mathematics education across two language contexts. In B. Greer and O. Skovesmose (Eds.), *Opening the Cage* (pp. 167-186), Sense Publishers, Rotterdam, Netherlands.

Traxler, J. (2007). Defining, discussing and evaluating mobile learning: The moving finger writes and having writ.... *The International Review of Research in Open and Distance Learning*, *8*(2). 9-24.

Turtiainen, E., Blignaut,. S., Els, C. Laine, T., & Sutinen, E. (2009). Story-based UFractions mobile game in South Africa: Contextualization process and multidimensional playing experiences. In Y. Cao et al. (Eds.), *Proceedings of the Second Workshop of Story Telling and Educational Games*. Aachen, Germany: RWTH Aachen University.

UNESCO (2012). United nations educational scientific and cultural organisation. *Turning on mobile learning in Africa and the Middle East*. Illustrative initiatives and policy implications. Retrieved November 20, 2012, from: http://unesdoc.unesco.org/images/0021/002163/216359E.pdf

Van Huyssteen, G., Puttkammer, M., & Schlemmer, M. (2007, January). *Developing web-based word-translators.* Paper presented at the LVSA/SAALA/SAVTO 2: Linguistics Society of Southern Africa (LSSA), South African Applied Linguistics Association (SAALA) and South African Association for Language Teaching (SAALT) conference, Potchefstroom, South Africa.

Vosloo, S., & Botha, A. (2009). *Mobile learning South African examples.* Paper presented at the Mobile learning institute summit. Retrieved October 12, 2012, from: http://www.slideshare.net/stevevosloo/mobile-learning-south-african-examples

Wong, L. H., Chai, C. S., Chin, C. K., Hsieh, Y. F., & Liu, M. (2012). Towards a seamless language learning framework mediated by the ubiquitous technology. *International Journal of Mobile Learning and Organisation*, *6*(2), 156-171.